# OBSERVATIONAL STUDY OF THE EVOLUTION OF MASSIVE BINARY STARS

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Six years ago an observational program on supergiant stars using CORAVEL was initiated at Geneva Observatory. About 1500 radial velocities were obtained out of a sample of 181 northern supergiants of F, G, K, M type. Nineteen new SB have been discovered and 16 others are suspected to be SB. The total rate of binary systems among northern supergiants is in the range of 31-38 % (Burki and Mayor, 1983). This value neither depends on spectral type nor luminosity class.

Note that a similar rate of binaries is found among cepheid stars: 25-35 % (Burki, 1983). This is quite normal since cepheids are simply F-G supergiants in a peculiar evolutionary phase.

The comparison of the binary rate among supergiants F0-K0Ib with that among their progenitors on the main sequence, B2-B5IV-V (Abt and Levy, 1978) is very interesting. Table 1 shows that the large fraction of binaries of period P<500 d on the main sequence is considerably reduced in the case of supergiants. Consequently, a large fraction of close binary systems never produce cool supergiants. Table 1 shows that this effect concerns about one third of the main sequence stars. Thus, this effect must be taken into account when stellar evolutionary models

| | B2-B5 IV,V | F0-K0 Ib |
|---|---|---|
| Single stars | 51 % | 65 % |
| Binary stars | | |
| P<500 d. | 29 % | 5 % |
| P>500 d. | 20 % | 30 % |

Table 1

are checked by comparing the number of stars in various zones of the HR diagram.



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## CIRCULARIZATION OF ORBITS

First of all let us define the quantity $P_{circ}$ for a binary system of period P and eccentricity e:

$$P_{circ} = P(1-e)^{3/2}$$

Thus, $P_{circ}$ corresponds to the period of the circular orbit having the distance $d_p$ between components at the periastron of the real elliptical orbit for radius. Of course, $d_p$ is an important parameter for the mechanisms of orbital circularization.

From the catalogue of Batten et al (1978) and the results of our own survey, the orbital elements are known for 25 SB having at least one supergiant component of type F to M. In Figure 1, the eccentricity e of these systems is plotted versus log $P_{circ}$ ($P_{circ}$ in days). The type of symbol refers to the luminosity class. In each luminosity class all systems with $P_{circ}$ shorter than a critical value have nearly circular orbits. The critical value is very well defined for class Ib: 350-440 days. This value is larger for classes Iab and Ia (1400-3900 days for class Ia).

A simple explanation can be given of the existence of this critical period. Figure 2 shows the variation of the radius of a 9 $M_{\odot}$ star with time (Maeder, 1981), during the supergiant stage (blue loop phase). At the first maximum of the radius, following the first, quick, crossing of the HR diagram, corresponds a limiting orbital period $P_{lim}$: in the binary systems which have a period smaller than $P_{lim}$ on the ZAMS, a mass exchange between the components will occur before the supergiant stage. By applying the method described in Kopal (1978) to the models of Maeder

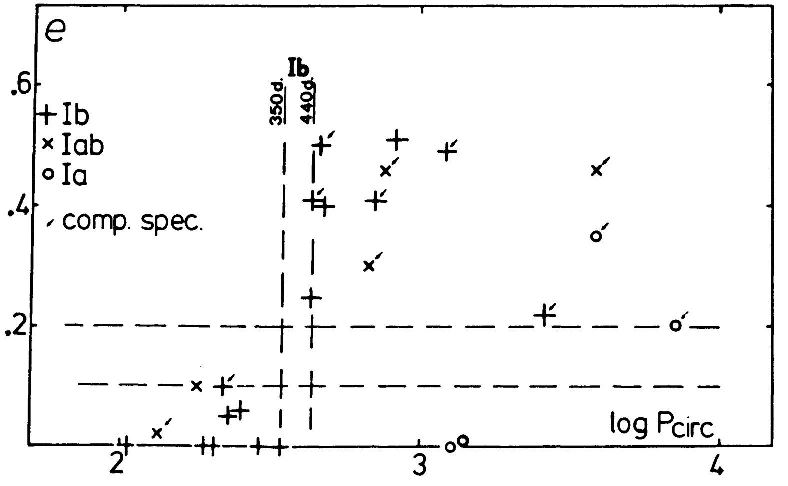


Figure 1

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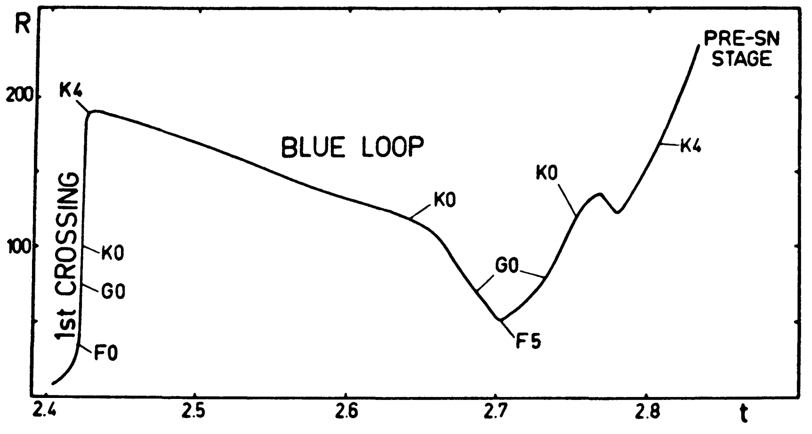


Figure 2

(1981), we found that $P_{lim}$ is in the range of 300-500 days for the systems containing a progenitor of Ib-type supergiant. This range for $P_{lim}$ is in good agreement with the critical value of the period deduced from Figure 1. Consequently, the orbit of the systems with shorter periods have probably been circularized by mass exchange. Note that the tidal effects certainly operate in addition to the circularization by mass exchange.

In Figure 1, the systems with a composite spectrum have been referred to by arrows. Almost all the systems with $e \geq 0.2$ have a composite spectrum whereas only two such cases are known in the systems with $e \leq 0.1$. In addition, the mass function $f_1(M)$ for the systems with $e \geq 0.2$ is on an average larger than the mass function for systems with $e \leq 0.1$ (see Burki and Mayor, 1983). These two facts indicate that: on an average, the secondary components are less massive in systems having been influenced by mass transfer than in the others. A probable explanation of this surprising fact is that, at least in several systems with $e \leq 0.1$, the star actually observed as a supergiant was the less massive component at the origin of the system.

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DISCUSSION

Lodén: In your statistics you got the sum of singular stars and binaries to be exactly 100 %. What has then happened to the triple stars and higher multiples?

Burki: They are included in the binary group.

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